

# (12) UK Patent Application (19) GB (11) 2 365 498 (13) A

(43) Date of A Publication 20.02.2002

(21) Application No 0118889.5

(22) Date of Filing 02.08.2001

(30) Priority Data

(31) 10038848

(32) 04.08.2000

(33) DE

(71) Applicant(s)

SKF GmbH

(Incorporated in the Federal Republic of Germany)  
Gunnar-Wester-Strasse 12, D-97421 Schweinfurt,  
Federal Republic of Germany

(72) Inventor(s)

Manfred Brandenstein  
Hans-Jürgen Friedrich  
Hubert Herbst  
Peter Horling

(74) Agent and/or Address for Service

Boult Wade Tennant  
Verulam Gardens, 70 Gray's Inn Road, LONDON,  
WC1X 8BT, United Kingdom

(51) INT CL<sup>7</sup>

F16C 33/64 // B21H 1/12, F16C 33/14 33/58

(52) UK CL (Edition T)

F2A AD44 AD66 A192 A5CQ A5CR A5C7 A6E2  
B3U U11

(56) Documents Cited

US 3710471 A

(58) Field of Search

UK CL (Edition S) B3U U11, F2A AD19 AD44 AD66  
A192 A5C7 A6E2

INT CL<sup>7</sup> B21H 1/12, F16C 33/04 33/14 33/20 33/58  
33/64

Online: EPODOC, WPI & PAJ.

(54) Abstract Title

**Bearing ring and the production thereof**

(57) A bearing ring having a raceway along which rolling elements roll/slide comprises first 1, 17 and second 2, 18 ring parts each having first 4, 20, 7, 22 and second 5, 19, 8, 21 circumferential surfaces and arranged concentrically to each other. The first ring part 1, 17 is harder than the second 2, 18 (which has a radially outwardly facing flange 9) and both are concentrically pressed together (with the aid of a first removable tool 10, 25 Fig 1b which presses the first and second parts to form a bearing ring, and a second removable tool 12, 27 Fig 3b which supports the second surface of the second part) so that the second surface 5, 19 of the first ring 1, 17 are plastically moulded (by an axial flow forming process) to the first surface 7, 22 of the second ring 2, 18. The second surface of the first ring part is cylindrically shaped, having a reduction in cross-section due to an increase in linear and nonlinear axial deviation towards the end face (Figs 2b and 4b).

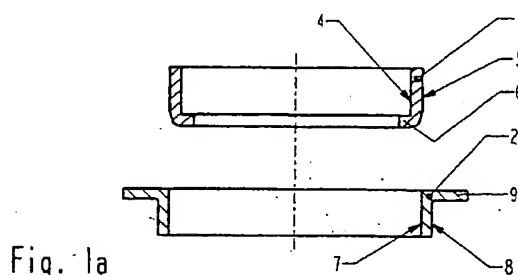
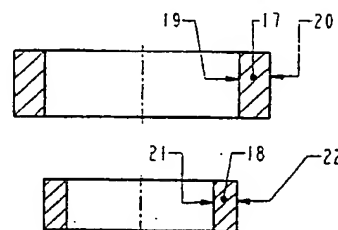


Fig. 3a



GB 2 365 498 A

BEST AVAILABLE COPY

1/6

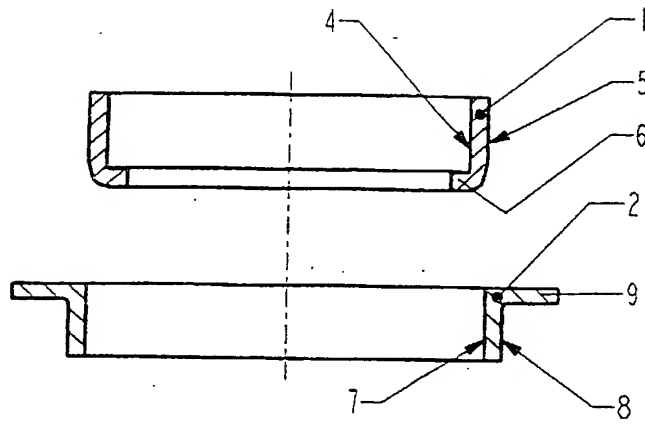


Fig. 1a

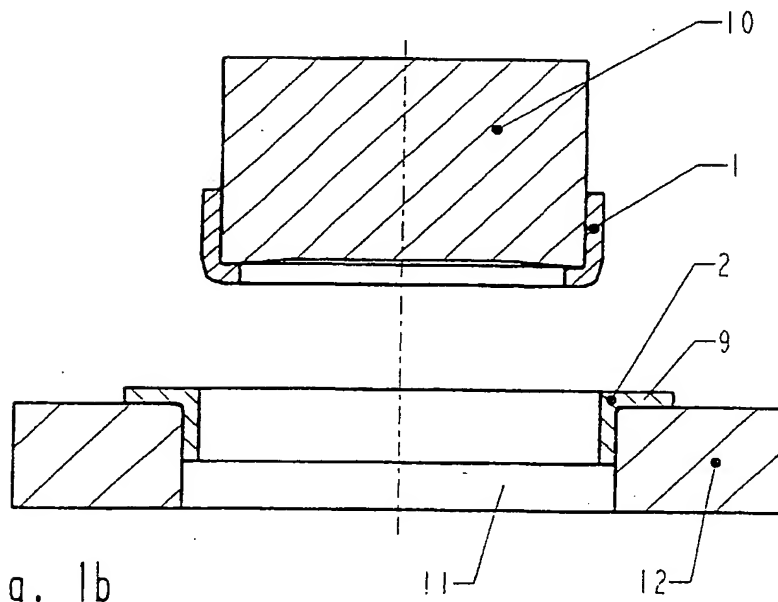
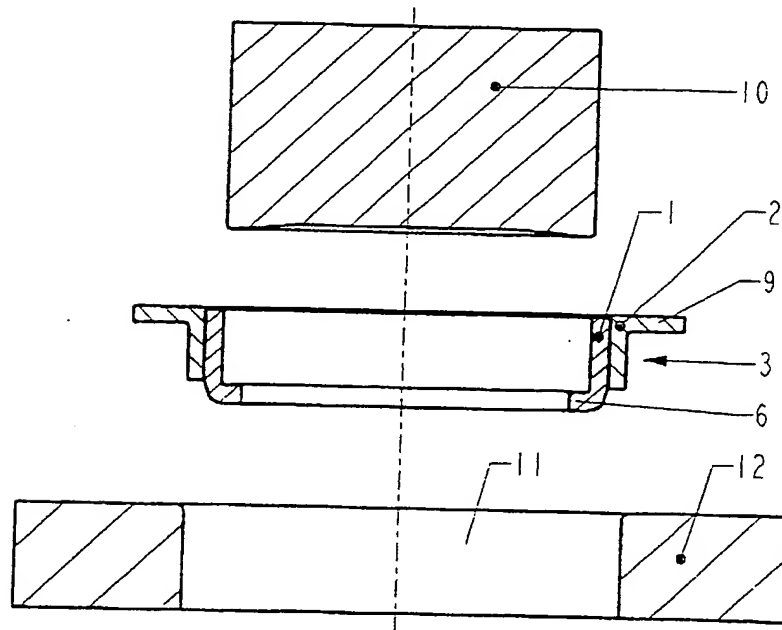
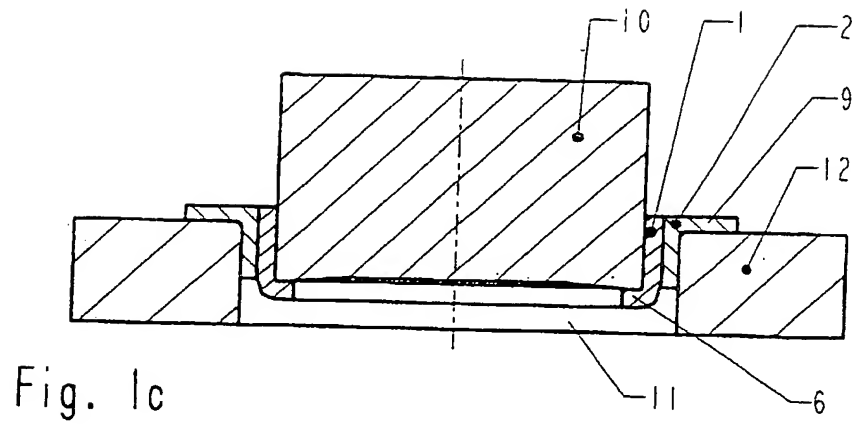


Fig. 1b





3/6

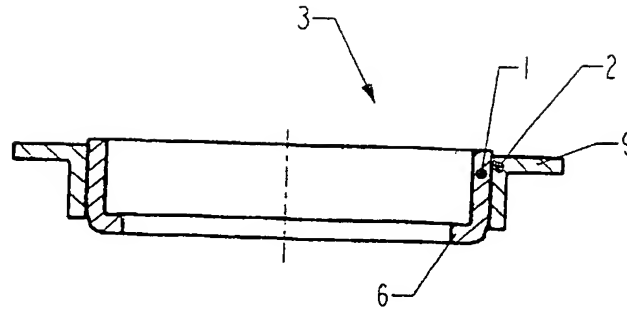


Fig. 2a

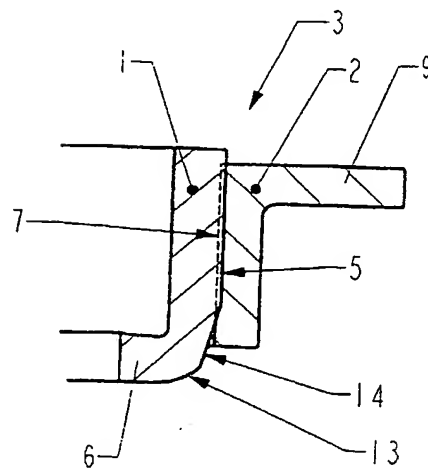


Fig. 2b



Fig. 3a

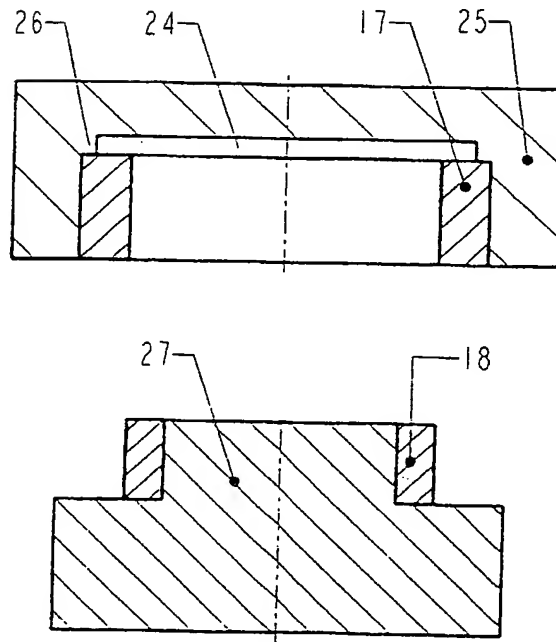
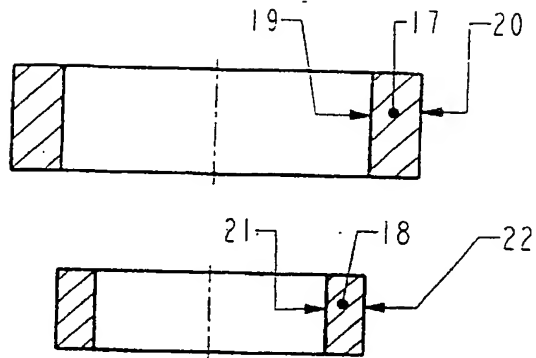


Fig. 3b



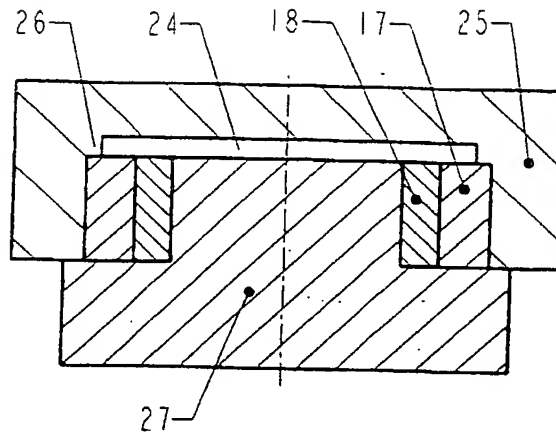


Fig. 3c

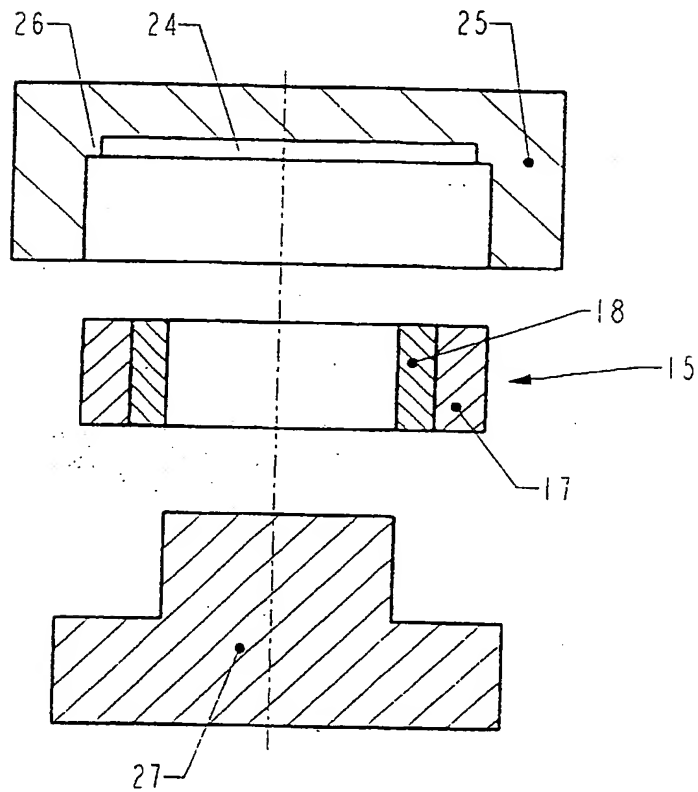
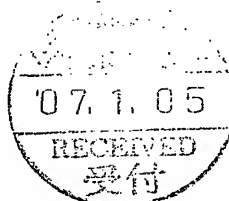


Fig. 3d



6/6

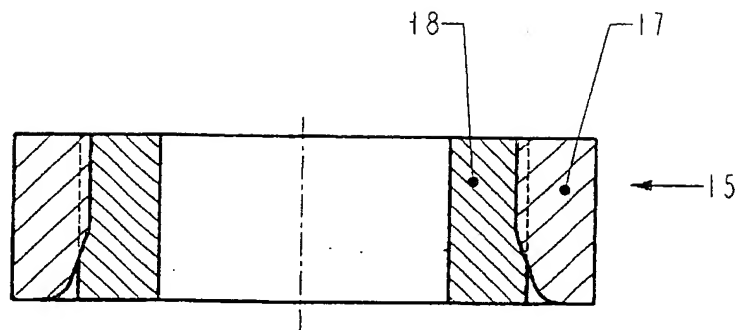


Fig. 4a

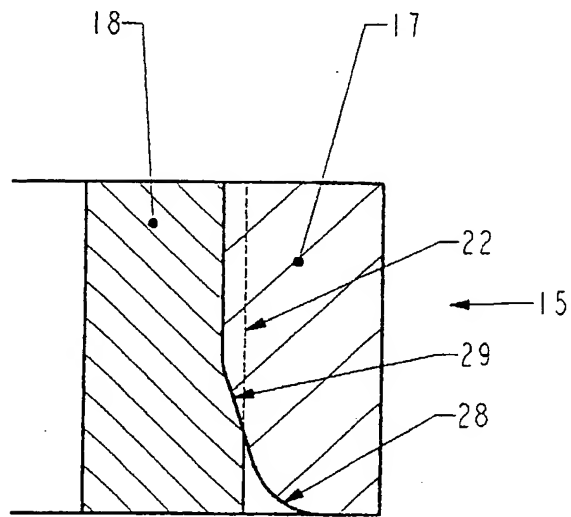


Fig. 4b

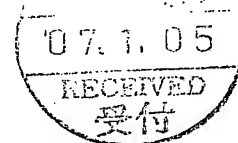


## BEARING RING

The invention relates to a bearing ring with a raceway along which rolling elements roll or with a sliding surface, and also to a method for producing such a bearing and a rolling bearing or plain bearing which has at least one such bearing ring.

A very wide variety of embodiments of bearing rings are known and can be produced in a multiplicity of ways. As a rule, the higher the requirements in respect of the dimensional stability of the bearing ring, the more complex and expensive are the production methods suitable therefor. The dimensional stability in the region of the raceway or the sliding surface of the bearing ring has especially strong effects on the technical properties of the bearing for which the bearing ring is being produced. In this case it is desirable for the diameter of the raceway or sliding surface to be maintained as accurately as possible, that is both in respect of its absolute value and in respect of any relative deviations, i.e. in respect of roundness. In this context, the problem also arises that the criteria within the framework of soft machine cutting of the bearing ring can be satisfied with acceptable costs but dimensional variations are brought about by the subsequently necessary hardening process owing to thermal distortion of the bearing ring. Therefore, to enable high accuracy requirements to be satisfied, it is necessary, as a rule, to carry out hard machining of the bearing ring after the hardening process until the desired final dimensions are achieved. However, this hard machining is comparatively complex and expensive.

DE 34 09 241 A discloses a method of producing axially accurate bearing seatings in light metal die-





castings, in which needle sleeves are pressed into calibrated sintered parts.

It is known from DE 21 17 018 C2 to press a hardened bearing bush into a non-hardened sleeve. The two-part bearing ring produced in this way is pressed into a bottom mould by means of a mandrel, the outer diameter of the bearing ring being calibrated by extrusion.

The invention is based on the object of providing a bearing ring which satisfies high requirements in respect of the dimensional stability in the vicinity of the raceway or sliding surface.

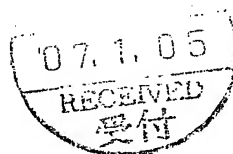
The bearing ring according to the invention is characterised in that it is of two-part design in a radial direction, i.e. it has first and second ring parts which are arranged concentrically to one another. It is essential for the bearing ring of the invention that the first and second ring parts are pressed together in such a way that the circumferential surface of the first ring part is plastically moulded by means of an axial flow forming process into the circumferential surface of the second ring part.

An extremely intimate bond is thus achieved between the two ring parts so that the ring parts permanently retain their shaping at the instant of being joined together.

The materials used for the first and second ring parts are advantageously of different hardnesses, a material of greater hardness being used for the first ring part.

If the bearing ring is an outer ring, it is advantageous for a flange to be formed on the first ring part or on the second ring part, which flange facilitates fastening of the bearing during the subsequently mounting of the bearing.

The first ring part deviates from a cylindrical shape in one axial portion of the circumferential surface,



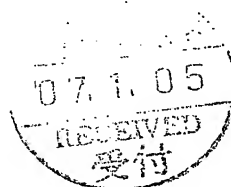
which abuts against the second ring part, in the sense of a reduction in the cross-section of the first ring part. In this case the axial portion is adjacent one of the end faces of the first ring part. This shaping firstly brings about advantages in the production of the bearing ring and secondly ensures a permanent bond of the two ring parts.

In the method according to the invention the first and second ring parts are pressed together in such a way that the two circumferential surfaces of the first ring part and the first circumferential surface of the second ring part are adjacent and the first circumferential surface of the first ring part and the second circumferential surface of the second ring part form the circumferential surfaces of the bearing ring thus produced.

The production method according to the invention is characterised in that the first ring part is firstly pressed in the vicinity of its first circumferential surface into a predeterminable by means of a first tool shape and, subsequently, by means of this first tool is pressed concentrically with the second ring part. In this case the second ring part bears against a second tool so as to prevent any deformation of the second ring part in the vicinity of its second circumferential surface. The contour of the second circumferential surface of the first ring part is plastically moulded by axial flow forming in the vicinity of the first circumferential surface of the second ring part.

The joining together of the first and second ring parts in accordance with the method of the invention has the advantage that the resultant bearing ring has a high precision circular cross-section in the vicinity of its raceway or sliding surface.

For the axial flow forming process an overlap between the first ring part and the second ring part is



advantageously chosen which is at least 100  $\mu\text{m}$  or which corresponds to the maximum wall thickness eccentricity of the second circumferential surface of the first ring part plus a value of at least 50  $\mu\text{m}$ .

As a result of the axial flow forming the wall thickness of the second ring part is reduced by 5 % to 20 %, preferably by 10 % to 18 %. Ideally, the wall thickness is reduced by approximately 12 %.

For the production of an outer ring the first tool is in the form of a solid cylinder and in the production of an inner ring the first tool has a cylindrical bore. The second tool is, in each case, formed complementarily to the first tool and differs from the first tool in respect of its dimensions by the wall thickness of the bearing ring to be produced.

The invention will be explained below with reference to the embodiments illustrated in the drawings, wherein:

Figures 1a to 1d show a schematic illustration of the sequence of steps involved in the method according to the invention for producing an outer ring, in sectional view;

Figures 2a and 2b show a sectional view of the outer ring according to the invention;

Figures 3a to 3d show a schematic illustration of the sequence of the steps involved in the method according to the invention for producing an inner ring, in a sectional view, and

Figures 4a and 4b show a sectional view of the inner ring according to the invention.

Figures 1a to 1d show a schematic illustration of the sequence of steps involved in the method according to



the invention for producing an outer ring. The figures show four snapshots of the method sequence which is illustrated in a highly schematic manner and which do not necessarily correlate to an optionally present time cycle in the sequence of the production method.

Figure 1a shows a first ring part 1 and a second ring part 2, from which an outer ring 3 is produced. The first ring part 1 is provided with an inner circumferential surface 4 and an outer circumferential surface 5. The inner circumferential surface 4 is in the form of a raceway, along which rolling elements roll, or in the form of a sliding surface. Furthermore, the illustrated embodiment of the first ring part 1 has a radially inward facing flange 6. The second ring part 2 is provided with an inner circumferential surface 7, an outer circumferential surface 8 and a radially outward directed flange 9.

As illustrated in Figure 1b, a cylindrical die 10 is pressed into the first ring part 1 in a first method step. The die 10 is manufactured very accurately and thus represents an almost perfect cylinder. This cylindrical shape is transferred to the inner circumferential surface 4 of the first ring part 1 during the pressing-in of the die 10 into the first ring part 1. The pressing-in takes place with a certain degree of overlap between the die 10 and the first ring part 1 so that, as a rule, elastic deformation of the first ring part 1 occurs with the result that the inner circumferential surface 4 of the first ring part 1 abuts precisely against the cylindrical surface of the die 10. By pressing in the die 10 the inner diameter of the first ring part 1 is thus brought to the desired dimension. Furthermore, any existing lack of roundness on the inner circumferential surface 4 of the first ring part 1 is substantially reduced. However, without any additional measures the aforesaid effects are again cancelled out when

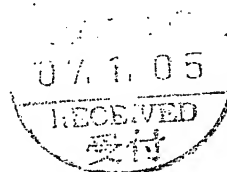


the die 10 is removed from the first ring part 1 insofar as the first ring part 1 has been elastically deformed. Suitable countermeasures, which prevent the first ring part 1 from springing back into its initial position, are taken during later steps in the method of the invention.

As is also illustrated in Figure 1b, the second ring part 2 is introduced into a cylindrical bore 11 of a tool 12 so that the second ring part 2 bears against the tool 12 with its outer circumferential surface 8.

Subsequently, the first ring part 1 is pressed into the second ring part 2 by means of the die 10. This is illustrated in Figure 1c. The overlap between the first ring part 1 and the second ring part 2 is chosen to be of such a size that during the pressing-in process a plastic deformation of the second ring part 2 takes place. In particular, an overlap is chosen which is at least 100  $\mu\text{m}$  or which corresponds to the magnitude of the maximum wall thickness eccentricity of the outer circumferential surface 5 of the first ring part 1 plus a value of at least 50  $\mu\text{m}$ . The maximum wall thickness eccentricity is defined here as the difference between the maximum and the minimum local radius in the cylindrically shaped region of the outer circumferential surface 5 of the first ring part 1 after the pressing-in of the die 10. As a rule, the maximum wall thickness eccentricity is approximately 60  $\mu\text{m}$  so that typically an overlap of 110  $\mu\text{m}$  or more is chosen. This is clearly more than is used for a conventional force fit.

During the pressing-in of the first ring part 1 into the second ring part 2, to ensure that the ring part 2 is exclusively or at least predominantly plastically deformed, a harder material is chosen for the first ring part 1 than for the second ring part 2. Moreover, in the region in which it contacts the second ring part 2 during the pressing-in, the first ring part 1 is so formed that during the pressing-



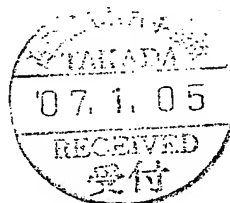
in the desired reshaping of the second ring part 2 takes place.

In detail, an axial flow forming process takes place during the pressing-in, in which the first ring part 1 serves as a flow forming die and the second ring part 2 is flow formed. The material of the first ring part 1 is compressed and displaced by the axial flow forming process, in which the wall thickness is substantially reduced. The wall thickness is reduced by a value which amounts to between 5 and 20 % of the original wall thickness. Preferably, the reduction is between 10 and 18 % and, ideally, a value of 12 % is attained.

As a result of the axial flow forming process the contour of the outer circumferential surface 5 of the first ring part 1 is moulded into the second ring part 2 and the two ring parts 1 and 2 are securely connected to one another. The connection is brought about by the frictional engagement prevailing between the two ring parts 1 and 2 and, depending on the sequence of the reshaping process, optionally also by form-locking.

As illustrated in Figure 1d, the die 10 and the tool 12 are again removed after the pressing of the first and second ring parts 1 and 2 into one another. Since the second ring part 2 has been plastically deformed and abuts securely against the first ring part 1, the shaping of the two ring parts 1 and 2 and thus especially the dimensionally accurate cylindrical shape of the inner circumferential surface 4 of the first ring part 1 is substantially maintained even after the removal of the die 10 and of the tool 12. The resultant outer ring 3 is thus provided with a high-precision raceway or sliding surface.

Figures 2a and 2b show a sectional view of a bearing ring according to the invention in the form of an outer ring



3. Figure 2b represents an enlargement of a detail of Figure 2a.

A dashed line indicates the outline of the inner circumferential surface 7 of the second ring part 2 before the pressing together of the ring parts 1 and 2. It is evident from Figure 2b that, after the pressing together of the two ring parts 1 and 2, the inner circumferential surface of the second ring part 2 deviates from this dashed line as a result of the plastic deformation of the second ring part and now coincides with the outer circumferential surface 5 of the first ring part 1, which has not been altered during the pressing process. In order to bring about the desired plastic deformation of the second ring part 2, the first ring part 1 is so formed that the diameter of the outer circumferential surface 5 decreases towards the end face with which the first ring part 1 is pressed into the second ring part 2. In this case the contour illustrated in the enlarged detail shown in Figure 2b has been found to be especially favourable. In this embodiment the outer circumferential surface 5 of the first ring part 1 takes the form of a convexly curved surface 13 in the transitional zone into the end face on which the flange 6 is also disposed, so that the outer circumferential surface 5 merges continuously into the outside of the flange 6. A tapered surface 14 adjoins the convexly curved surface 13 on the outer circumferential surface 5, within which surface the outer diameter of the ring part 1 constantly increases up to a maximum value. Over the remaining axial region the outer diameter remains constant at this maximum value, i.e. the outer circumferential surface 5 is of cylindrical shape.

To ensure that the flow forming effects required for the production of the outer ring 3 can be obtained, values of between  $7^{\circ}$  and  $15^{\circ}$  are chosen for the angle which



the tapered surface 14 forms with the cylindrical region of the outer circumferential surface 5. A maximum radius of 0.3 mm can be formed in the vicinity of the transition between the tapered shape and cylindrical shape.

As a result of the aforementioned shaping, upon pressing the first ring part 1 into the second ring part 2, no material or only a little material is abraded and, instead, deformation and/or compression of the material of the second ring part 2 takes place particularly in a radially outward direction. Depending on the application, variations from the above-described shaping are also possible, in which case a constant transition without edges from the outer circumferential surface 5 into the end face of the first ring part 1 is generally found to be advantageous.

Figures 3a to 3d show a schematic illustration of the sequence of the steps involved in the method according to the invention for producing an inner ring 15. In principle, the production of the inner ring 15 takes place analogously to the production of the outer ring 3. The inner ring 15 is produced from a first ring part 17 and a second ring part 18.

In the embodiment illustrated in Figure 3a the first ring part 17 is in the form of a cylindrical sleeve or flange. The first ring part 17 has an inner circumferential surface 19 and an outer circumferential surface 20 which is formed as a raceway along which rolling elements roll, or is formed as a sliding surface. The second ring part 18 has an inner circumferential surface 21 and an outer circumferential surface 22.

According to Figure 3b to produce the inner ring 15 the first ring part 17 is pressed into a very accurately produced bore 24 of a tool 25 until it abuts with its end face against a circumferential shoulder 26 in the bore 24.





In this case the overlap is chosen so that, after the pressing-in, the outer circumferential surface 20 of the first ring part 17 abuts closely against the bore 24 of the tool 25 and thus assumes the high-precision cylindrical shape of the bore 24. A cylindrical die 27 is introduced into the second ring part 18, on which the second ring part 18 can bear with its inner circumferential surface 21 in the subsequent pressing process.

As illustrated in Figure 3c, in a subsequent operating step the two annular parts 17 and 18 are pressed together, whereupon the first ring part 17 is pushed over the second ring part 18. During the pressing process the first ring part 17 remains in the bore 24 and the second ring part 18 remains on the die 27 so that the inner circumferential surface 21 of the second ring part 18 and in particular the outer circumferential surface 20 of the first ring part 17 remain undeformed. However, during the pressing together, the outer circumferential surface 22 of the second ring part 18 is so deformed by the first ring part 17 that it assumes the contour of the inner circumferential surface 19 of the first ring part 17. For this purpose an overlap is chosen which is at least 100  $\mu\text{m}$  or which is determined analogously to the mode of procedure for producing the outer ring 3, that is to say from the maximum wall thickness eccentricity of the inner circumferential surface 19 of the first ring part 17. Since a harder material is used for the first ring part 17 than for the second ring part 18 the inner circumferential surface 19 of the first ring part 17 remains substantially unaltered.

An axial flow forming process also takes place during the production of the inner ring 15. The first ring part 17 serves as a flow forming die and the second ring part 18 is flow formed, during which material compression and material displacement take place, as does a reduction in



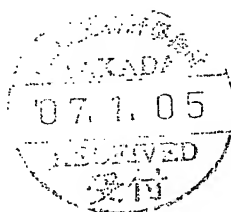
the wall thickness of the second ring part 18. The values for the reduction in the wall thickness correspond to the details which were given for the outer ring 3.

As a result of the moulding of the contour of the inner circumferential surface 19 of the first ring part 17 into the outer circumferential surface 22 of the second ring part 18, an intimate bond occurs between the two annular parts 17 and 18, which is retained after removal of the die 27 and the tool 25 and has a shape-stabilising effect. The result of this is that the precise cylindrical shape of the outer circumferential surface 20 of the first ring part 17 produced by means of the tool 25 is also substantially maintained.

The finished inner ring 15 is illustrated in Figure 3d after removal from the tool 25 and from the die 27.

Figures 4a and 4b show a sectional view of a bearing ring according to the invention in the form of an inner ring 15. Figure 4b illustrates an enlarged detail of Figure 4a.

In a similar manner to the outer circumferential surface 5 of the first ring part 1 of the inner ring 3, the inner circumferential surface 19 of the first ring part 17 of the inner ring 15 is so formed that the desired plastic deformation of the annular part 18 during the pressing together of the two ring parts 17 and 18 is made possible. For this purpose the inner circumferential surface 19 of the first ring part 17 is in the form of a convexly curved surface 28 in the vicinity of at least one of the end faces of the first ring part 17 so that the first ring part 17 widens radially towards this end face. Adjacent the convexly curved surface 28 is a tapered surface 29, within which the inner diameter of the first ring part 17 decreases constantly to a constant value which the inner circumferential surface 19 has over the remaining axial region. The angle which the tapered surface 29 forms with



the region of constant inner diameter amounts to between 7° and 15°. The inner circumferential surface 19 can be curved in the transition between the tapered surface 29 and the region of constant inner diameter, in which case the radius of curvature amounts to a maximum of 0.3 mm. To illustrate the effects of the reshaping process, the outline of the outer circumferential surface 22 of the second ring part 18 before the pressing-on of the first ring part 17 is indicated by a dashed line.

In a variant of the invention, the raceway or the sliding surface of the bearing ring is not cylindrical but is tapered. Accordingly, a tapered die 10 or a tool 25 with a tapered bore 24 is used. In principle, the design of the die 10 or the bore 24 of the tool 25 depends respectively on the desired contour of the raceway or sliding surface.

The bearing ring according to the invention can be used in an identical manner to conventional one-part bearing rings, i.e. the outer ring 3 and the inner ring 15 according to the invention can be combined to form a plain bearing or a rolling bearing. Likewise the bearing ring according to the invention can also be combined with a conventional one-part bearing ring to form a plain bearing or a rolling bearing.



## CLAIMS

1. A bearing ring with a raceway along which rolling elements roll or with a sliding surface, and also with a first ring part with a first circumferential surface, which is in the form of a raceway or sliding surface, and with a second circumferential surface, a second ring part with a first circumferential surface and a second circumferential surface, wherein the first ring part, and the second ring part are arranged concentrically to one another, wherein the first ring part and the second ring part are so pressed together that the second circumferential surface of the first ring part is moulded plastically by an axial flow forming process into the first circumferential surface of the second ring part.
2. A bearing ring according to Claim 1, wherein the first ring part is of greater hardness than the second ring part.
3. A bearing ring according to any one of the preceding Claims, wherein the second circumferential surface of the first ring part is cylindrically shaped in a first axial portion and in at least a second axial portion deviates from a cylindrical shape towards the end face of the first ring part in the sense of a reduction in the cross-section of the first ring part.
4. A bearing ring according to Claim 3, wherein the deviation increases continuously towards the end face.
5. A bearing ring according to either Claim 3 or Claim 4, wherein the deviation increases towards the end face in sections linearly and in sections non-linearly.



6. A bearing ring according to any one of the preceding Claims, wherein the second ring part has a radially outwardly facing flange.

7. A rolling bearing or plain bearing, wherein it has a bearing ring according to any one of Claims 1 to 6.

8. A method for producing a bearing ring which has a raceway along which rolling elements roll or a sliding surface, wherein

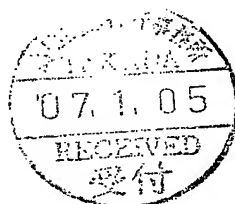
a bearing ring is produced from a first ring part with a first circumferential surface which is in the form of a raceway or a sliding surface and with a second circumferential surface, and from a second ring part with a first circumferential surface and a second circumferential surface, a first tool engages with the first circumferential surface of the first ring part and the first circumferential surface is pressed into a predeterminable shape,

a second tool supports the second circumferential surface of the second ring part,

the first tool presses the first ring part together with the second ring part to form a bearing ring with a first ring part and a second ring part arranged concentrically to one another, and the contour of the second circumferential surface of the first ring part is moulded plastically by means of axial flow forming into the first circumferential surface of the second ring part,

the first tool is removed from the first ring part and the second tool is removed from the second ring part.

9. A method according to Claim 8, wherein for the axial flow forming process an overlap between the first ring part and the second ring part is chosen, which is at least 100  $\mu\text{m}$  or which corresponds to the maximum wall thickness



eccentricity of the second circumferential surface of the first ring part after engagement of the first tool plus a value of at least 50  $\mu\text{m}$ .

10. A method according to Claim 8 or Claim 9, wherein the wall thickness of the second ring part is reduced, during the axial flow forming process.

11. A method according to Claim 10, wherein the wall thickness is reduced by between 5 % and 20 %.

12. A method according to Claim 11, wherein the wall thickness is reduced by between 10% and 18%.

13. A method according to Claim 11 or Claim 12, wherein the wall thickness is reduced by approximately 12 %.

14. A method according to any one of Claims 8 to 13, wherein the first ring part is elastically deformed by the first tool.

15. A method according to any one of Claims 8 to 14, wherein the deformation of the first ring part pressed together with the second ring part, which was brought about before the pressing-together by means of the first tool, is substantially maintained after removal of the first tool.

16. A bearing ring as hereinbefore described with reference to or as shown in the accompanying drawings.

17. A method for producing a bearing ring as hereinbefore described with reference to or as shown in the accompanying drawings.





Application No: GB 0118889.5  
Claims searched: All (1-17)

16  
Examiner: David J Evans  
Date of search: 11 October 2001

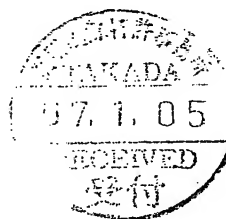
**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK Cl (Ed.5): F2A (AD19, AD44, AD66); B3U (U11)  
Int Cl (Ed.7): F16C (33/04, 33/14, 33/20, 33/58, 33/64); B21H (1/12)  
Other: Online: EPODOC, WPI & PAJ.

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	US 3710471 A (PITNER) whole document of interest, especially see figs 7 & 8, column 1 line 59 to column 2 line 22, column 4 line 47 to column 5 line 6 and abstract.	



X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☐ BLACK BORDERS

☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES

☒ FADED TEXT OR DRAWING

☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING

☐ SKEWED/SLANTED IMAGES

☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS

☐ GRAY SCALE DOCUMENTS

☐ LINES OR MARKS ON ORIGINAL DOCUMENT

☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY

☐ OTHER: \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**